Dipion and dielectron production in quasi-free np reactions with HADES *

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The origin of the yield excess in the inclusive dielectron production in np over the pp collisions measured by HADES [1] still needs to be clarified to provide a global reliable interpretation of dielectron spectra measured in nuclear collisions by HADES. Several attempts to solve this issue by including a contribution from off-shell ρ meson were recently proposed [2,3,4]. Since the main decay of the ρ is the channel with two charged pions, an analysis of this channel provides an important constraint for dielectron spectra [5]. Furthermore, the results on dipion production provide valuable verification of the di-baryon formation, recently reported by the WASA collaboration [6,7], in a complementary phase space region as covered by HADES. We report on results on exclusive dipion and dielectron production in np collisions in the deuterium formation channel.

Signal selection

The quasi-free np reaction was studied using measurements of the dp reaction with a deuterium beam of 2.5 GeV. The quasi-free np reaction was tagged by the proton spectator detection at small angles (0.3-7°) in the Forward Wall with a velocity close to the beam velocity. Since for both $np \rightarrow de^+e^-$ and $np \rightarrow d\pi^+\pi^-$ reactions, the deuteron angular distribution is very forward peaked, very few deuterons reach the HADES detector, which covers polar angles from 18° to 85°, while the detection in the Forward Wall (FW) is more suited. Due to the large statistics in the $np \rightarrow d\pi^+\pi^-$ channel, both cases (deuteron detected in FW or in HADES) were investigated, while for the more rare $np \rightarrow de^+e^-$ channel, only the detection of the deuteron in the FW was investigated. Deuterons are identified in HADES with a very high purity using the correlation between time-of-flight and momentum. For the deuteron identfication in the FW a coplanarity constraint on all particles in the final state was used, in addition to cuts on the time-of-flight to suppress events corresponding to the unbound processes ($np \rightarrow np\pi^+\pi^-$ or $np \rightarrow npe^+e^-$) [5].

Dipion production

After a subtraction in each bin of the background contribution using the coplanarity condition, the experimental distributions of the $pn \rightarrow d\pi^+\pi^-$ have been compared to the predictions of a model provided by M. Bashkanov [6],

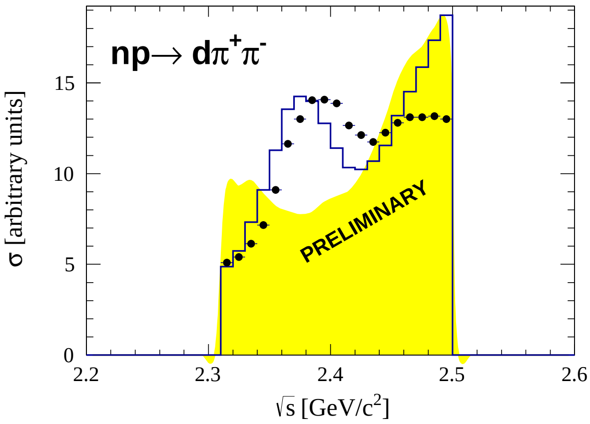

Figure 1: Cross-sections (full symbols) for the quasi-free $pn \rightarrow d\pi^+\pi^-$ reaction deduced from measurements with a deuteron beam at 2.5 GeV, where the two pions are detected in HADES and an additional charged particle is detected in the Forward Wall [5]. The blue histogram shows the result of a simulation taking into account double $\Delta(1232)$, $N(1440)$ and $N(1520)$ excitation, as well as the contribution of a dibaryon with a mass of 2.38 GeV. The data have been normalized using quasi-free pp elastic scattering and are compared to the model predictions on the same absolute scale. The yellow area shows the distribution expected for a phase space simulation of the reaction with an arbitrary normalization.

which includes conventional t-channel processes (double $\Delta(1232)$, $N(1440)$ and $N(1520)$ excitation), as well as the contribution of a dibaryon (d*) with a mass 2.38 GeV and a width $\Gamma \sim 70MeV$, as suggested by the results of the WASA collaboration in the $pn \rightarrow d\pi^0\pi^0$, $pn \rightarrow d\pi^+\pi^-$ and $pp \rightarrow d\pi^+\pi^0$ reactions [2,3]. The model underestimates the yields measured in the case of the deuteron detected in HADES, which might be due to a contamination of non quasi-free processes. However, when the deuteron is detected in the FW, a reasonable description of the yields and differential distributions is achieved, while the conventional sources alone underestimate the measured yields [5]. A procedure to unfold the neutron momentum distribution and extract the $np \rightarrow np\pi^+\pi^-$ cross section as a function of the center-of-mass energy ($\sqrt{s}$) of the np pair was applied to the experimental data, as well as to simulated events generated either with the model [6] or with a phase-space model. The results are shown in Fig.1. The data have been normalized using quasi-free pp elastic scatter-

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ing events and are compared to the model predictions on the same absolute scale, which is displayed here in arbitrary units. The results obtained with the phase space distributions have an arbitrary normalization. A peak is observed in our experimental data. Even though located at a slightly larger $\sqrt{s}$, it is very similar to the one predicted by the model, where it is attributed to the d* contribution. Though systematic effects still need to be investigated, this result seems to confirm the observations of the WASA collaboration.

Dielectron production

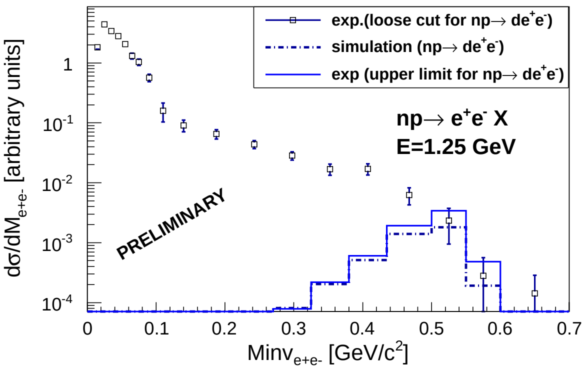

Figure 2: $np \rightarrow Xe^+e^-$ reaction as a function of the e^+e^- invariant mass [5]. The empty squares and full blue line show experimental results corresponding respectively to a loose cut based on time-of-flights to enhance the contribution of the $np \rightarrow de^+e^-$ channel and to the upper limit for this reaction. The results of a simulation of the $np \rightarrow de^+e^-$ process are shown as a dot-dashed blue line. The data have been normalized using quasi-free pp elastic scattering and are compared to the model predictions on the same absolute scale.

In the dielectron channel, no signal for $np \rightarrow de^+e^-$ reaction is visible. However, the Feldman $\&$ Cousins method was applied to extract an upper limit for the differential cross sections of this reaction using constraints from the coplanarity condition. To show the power of this method, this upper limit is displayed in Fig. 2, in comparison to the experimental differential cross sections obtained after appplying only time-of-flight cuts on the FW hits. This upper limit is in agreement with the predictions of [3], where the $np \rightarrow d\gamma$ differential cross sections are deduced from the known photo disintegration ($np \rightarrow d\gamma$) cross sections and the extension to virtual photon emission is based on the Vector Dominance Model. However, it is overestimated by 60$\%$ by the model [4], which uses an off-shell ρ production due to the $\Delta\Delta$ Final State Interaction.

References

[1] G. Agakichiev et al., Phys. Lett. **B690** (2010) 118.

[2] R. Shyam and U. Mosel Phys. Rev. **C82** (2010) 062201.

[3] B. Martemyanov et al. Phys. Rev. **C84** (2011) 047601

[4] M. Bashkanov and H. Clement Eur. Phys. J. **A50** (2014) 107.

[5] H. Kuc, PhD thesis, Paris-Sud University, Dec. 2014.

[6] P. Alardson et al., Phys. Rev. Lett. **106** (2011) 242302.

[7] P. Alardson et al., Phys. Lett. **721** (2013) 229.

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